N87-25887

# RARE GAS ANALYSIS OF SIZE FRACTIONS FROM THE FAYETTEVILLE METEORITE

Jim L. Jordan
Assistant Professor
Department of Geology
Lamar University
Beaumont,TX 77710


## Abstract

Eight size separates of grains from the Fayetteville meteorite ranging from less than 20 microns to greater than .1 millimeter are being analyzed for their rare gas elemental and isotopic composition.At this time measurements on five of the samples have been performed. All five reveal a mixture of solar, planetary, cosmic ray produced and radiogenic gases.The solar component is of particular interest since it suggest that the meteorite may represent a fragment of an ancient protoplanetary regolith which was exposed to the solar wind.Solar wind elements are implanted in the outer few hundred Angstroms of exposed grains and are therefore expected to be surface correlated.At present the data do not suggest that such a correlation exists,but the final conclusion must await further analyses and data reduction.

1. Introduction

Elemental and isotopic studies of meteoritic and lunar material have been extensively used to characterize the physical and chemical environment in which these materials formed and currently exist. Rare gases are particularly attractive for this purpose because their low abundance allows for the effects of processes such as cosmic ray induced nuclear reactions and radioactive decay to be detected easily above the trapped primordial gas background. The inert character and wide mass range of these gases make them particularly useful monitors of the thermal history of planetary materials. The ages and duration of these events may be determined from those rare gases that are products of nuclear reactions and radioactive decay as well.

Before the Apollo program meteorites provided the most important source of information on the nature of solids in the extraterrestrial environment, both past and present.Unlike the Earth , most meteorites show little evidence for having experienced severe thermal metamorphism and therefore become useful objects of study for the earliest events in the solar system , including the formation itself. The Apollo missions added abundant information about lunar materials to the realm of our knowledge regarding extraterrestrial matter.Since the moon has at present no magnetic field it is a passive object to solar wind,solar flares,and galactic cosmic rays and thus is a good target for recording these radiations in the grains at its surface.A very large database for this record now exists from laboratory measurements made on lunar soil samples.Lunar soils have proven to be particularly useful in providing well defined compositions for solar wind implanted particles.Since solar wind elements have typical energies of 1 keV/nucleon they are implanted in the outer few hundred Angstroms of exposed grains and are therefore expected to be surface correlated. Analyses of size fractions of lunar soils show such a correlation exist for solar wind implants and these surface correlated elements have been used to define the solar wind composition albeit fractionated by a large number of regolith processes (see for example [1]).

One of the goals of lunar soil studies has been to determine the composition of the ancient solar wind. Indeed such information would not only aid in the understanding of the behavior of the sun at the time of solar system formation 4.5 billion years ago, but it would enhance our knowlege of stellar processes in general. The soil studies have failed to provide the answer to this question since the history of the regolith of the moon is extremely complex. Down to a depth of greater than a meter evidence exist for grains having been exposed to the solar wind, indicating that they had resided at the very surface at one time [2]. There has not been any satisfactory means found thus far, however, for determining when and how long an individual grain was at the very surface.

To address the problem of the ancient solar wind interest has turned once again to meteorites.Some meteorites may represent the surface of their parent body which apparently broke up very early in the history of the solar system .These "regolith" meteorites have probably recorded an earlier solar wind.Rare gas analyses of these meteorites have revealed that they are "gas-rich" compared to others and that the composition is both elementally and isotopically distinct from other meteorites as well [3]. Lunar samples confirmed the long standing suspicion that a large portion of the gas in these objects is from the solar wind.

For the aforementioned reasons we have undertaken the study of the Fayetteville meteorite, the most gas rich of this class of meteorites.Our goal was to carry out rare gas analyses of several size separates of a disaggregated portion of this meteorite to determine if a surface correlation exists and better define the composition of this gas. A large number of rare gas analyses have been performed on Fayetteville, but none were done on size fractions from a disaggregated sample [4,5,6,7,8,9, 10,11,].It is indeed a challenging task to disaggregate a compacted meteorite into its constituent grains and the meaningfulness of the rare gas data depends in part on the success of that experiment.It represents an important first step for expanding our understanding of parent body regoliths and their record of the ancient solar wind.

2.Experimental

Prior to rare gas analyses 561 mg of the Fayetteville meteorite was disrupted by D.McKay and co-workers with a freeze-thaw technique using alternating cycles of liquid nitrogen and hot water baths.A total of 24,440 cycles taking 64.5 days were performed before stopping the procedure because of Fe oxidation.Disaggregation was not complete. Following this procedure the disrupted portion was sieved into seven size fractions ranging from less than 20 microns to 1 mm in diameter.

Small masses of each size fraction were wrapped in aluminum foil "boats" and loaded in the ultrahigh vacuum system (<10E-8 mmHg) gas extraction system.Gas extraction was performed by heating the sample at 1550 C in an RF induction furnace.The evolved gas cleaned with a hot Ti-getter and two Zr-getters. Separation of lighter from heavier gases was accomplished through "freezing" gases on a charcoal finger with liquid nitrogen (Ar,Kr,Xe bound;He and Ne measured),liquid nitrogen+isobutonal (Ar freed,some Kr),and liquid nitrogen+hexonal (Kr freed,some Xe). Xe was released from the charcoal finger with hot water.

The separated gases are admitted through a gas inlet valve to a static mode rare gas mass spectrometer.The sensitivities for He,Ne,Ar are of the order of magnitude 10E-10 cc/mv and 10E-13 cc/mv for Kr and Xe when the accelerating voltage , ionization potential,electron current,magnetic field, and electrometer resistance are appropriately set. The sensitivities are accurately determined using air pipettes (1/10th cc) as standards.Sample gas isotopes were measured by computer driven magnetic field changes (peak jumping) 10 - 15 times and extrapolation of peak values and isotopic ratios to the time of gas inlet was done by fitting the data to a fourth order polynomial.

3.Results and Discussion

The rare gas concentrations of five of a total eight samples (including 1 undisrupted sample) measured thus far are listed in Table 1.Elemental ratios of the same are given in Table 2 and isotopic ratios may be found in Tables 3 - 5.It is clear from all of these data that there is no correlated variation with the diameter of the grains obtained through the freeze - thaw technique.Our results agree well with previous measurements of bulk samples of Fayetteville suggesting that the failing correlation was not the result of an experimental mishap.

The failure to obtain a correlation of rare gas contents with grain size may be due to the disruption technique.It is not absolutely certain that any grain size fraction is made up of completely disaggregated material.Grains may have broken across their boundaries as well.This technique must be compared with others before one can relate these results to grains as they were in the regolith.

4.Conclusions

It should not be concluded at this stage that the solar wind surface correlation never existed in the regolith of the Fayetteville parent body.One should first appeal to other methods of extracting this information such as disruption by sonification or stepwise heating.The former method will call for additional rare gas measurements of grain size separates.The latter method allows for measurement of bulk sample but requires many temperature steps.In this procedure advantage is taken of the different activation energies of rare gas components in meteoritic minerals.Both of these methods will be investigated in the future.

Table 1

FAYETTEVILLE RARE GAS DATA FOR GRAIN SIZE SEPARATES
ccSTP/g

| SIZE (MICRONS) | | 3 HE E-6 | 4 HE E-3 | 22 NE E-6 |
|---|---|---|---|---|
| <20 | | 8.351 | 8.282 | 1.993 |
| 20-45 | | 1.362 | 3.18 | 1.771 |
| 45-90 | * | | | |
| 90-150 | | 4.069 | 12.072 | 3.0235 |
| 150-250 | * | | | |
| 250-500 | * | | | |
| 500-1000 | | 2.99 | 8.13 | 2.0397 |
| >1000 | | 2.465 | 6.971 | 2.137 |

| SIZE (MICRONS) | | 36 AR E-6 | 86 KR E-10 | 136 XE E-10 |
|---|---|---|---|---|
| <20 | | 1.207 | 82.86 | 90.78 |
| 20-45 | | 0.801 | 4.921 | 2.631 |
| 45-90 | * | | | |
| 90-150 | | 1.666 | 8.585 | 5.942 |
| 150-250 | * | | | |
| 250-500 | * | | | |
| 500-1000 | | 0.442 | 12.14 | 8.832 |
| >1000 | | 1.105 | 4.802 | 1.735 |

*) Not measured at this time

Table 2 ELEMENTAL RATIOS

| SIZE (MICRONS) | 4/20 | 20/36 | 36/84 | 84/132 |
|---|---|---|---|---|
| <20 | 363.5 | 18.9 | 44.7 | 0.998 |
| 20-45 | 168.9 | 23.5 | | |
| 45-90 | | | | |
| 90-150 | 353.6 | 20.5 | 596.4 | 1.537 |
| 150-250 | | | | |
| 250-500 | | | | |
| 500-1000 | 352.4 | 52.2 | 111.8 | 1.485 |
| >1000 | 289.6 | 21.8 | 700.6 | 2.942 |

Table 3 ISOTOPIC RATIOS - LIGHT GASES

| | 4/3 | 20/22 | 21/22 |
|---|---|---|---|
| <20 | 991.6 | 11.43 | 0.0547 |
| 20-45 | 2334.2 | 10.63 | 0.0876 |
| 45-90 | | | |
| 90-150 | 2967.1 | 11.29 | 0.059 |
| 150-250 | | | |
| 250-500 | | | |
| 500-1000 | 2719.1 | 11.31 | 0.0621 |
| >1000 | 2827.8 | 11.26 | 0.0517 |

| | 36/38 | 40/36 |
|---|---|---|
| <20 | 5.207 | 36.61 |
| 20-45 | 5.018 | 43.14 |
| 45-90 | | |
| 90-150 | 5.189 | 29.47 |
| 150-250 | | |
| 250-500 | | |
| 500-1000 | 5.011 | 35.05 |
| >1000 | 5.08 | 30.02 |

Table 4 VALUES OF $^{i}KR$ / $^{86}KR$

| ISOTOPE | <20 | 90-150 | 500-1000 | >1000 |
|---|---|---|---|---|
| 78 | 0.0623 | 0.194 | 0.0803 | 0.1422 |
| 80 | 0.134 | 0.1651 | 0.1439 | 0.1624 |
| 82 | 0.6609 | 0.6862 | 0.6677 | 0.6855 |
| 83 | 0.6574 | 0.6723 | 0.6588 | 0.6756 |
| 84 | 3.257 | 3.253 | 3.256 | 3.284 |

Table 5 VALUES OF $^{i}XE$ / $^{136}XE$

| ISOTOPE | <20 | 20-45 | 90-150 | 500-1000 | >1000 |
|---|---|---|---|---|---|
| 124 | 0.01183 | 0.04835 | 0.02133 | 0.01372 | 0.0214 |
| 126 | 0.01146 | 0.04639 | 0.0216 | 0.01332 | 0.02158 |
| 128 | 0.2159 | 0.3294 | 0.2616 | 0.2288 | 0.2702 |
| 129 | 2.885 | 3.167 | 3.302 | 3.24 | 3.355 |
| 130 | 0.4502 | 0.5096 | 0.485 | 0.4636 | 0.4983 |
| 131 | 2.344 | 2.42 | 2.448 | 2.386 | 2.493 |
| 132 | 2.979 | 3.044 | 3.058 | 3.014 | 3.089 |
| 134 | 1.169 | 1.221 | 1.198 | 1.177 | 1.201 |

References


1. P.Eberhardt,J.Geiss,H.Graf,N.Groegler,U.Kraehenbuehl H.Schwaller,J.Schwarzmueller,A.Stettler,Science 167, 558 (1970).

2. D.D.Bogard and W.C.Hirsch,Proc.Lunar Sci. Conf.6th, 2057 (1975).

3. R.O.Pepin and P.Signer,Science 149,253 (1965).

4. D.C. Black,Geochem.Cosmochem.Acta 36,347 (1972).

5. H.Hintenberger,H.Koenig,L.Schultz,and H.Waenke, Z. Naturf. 19A,327 (1964).

6. O.K.Manuel and P.K.Kuroda,J.Geophys.Res.69,1413 (1967).

7. O.K.Manuel,Geochem.Cosmochem.Acta 31,2413 (1967).

8. G.H.Megrue,Science 157,1555 (1967).

9. G.H.Megrue,Meteorite Research (Ed. P.M.Millman), 922 Reidel,Dordrecht (1969).

10. O.Mueller and J.Zaehringer,Earth Planet Sci.Lett. 1,25 (1966).

11. J.Zaehringer,Meteortika 27,25 (1966).